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13. ABSTRACT (Maximum 200 words) We have conducted four studies on three different but related materials. The first is a temperature study of a pseudomorphic epilayer of ZnSe on GaAs, where we measured the temperature dependence of the interlayer biaxial strain. The measurement was performed via photomodulation spectroscopy, tracking the splitting of the heavy - light hole transition energies. This method provides an accurate and direct measure of the strain. In the second study we investigated the pressure dependence of the polarized modulated optical reflectivity in an ordered alloy of InGaP ₂ as a function of hydrostatic pressure, and determined the pressure coefficients of the direct transitions as well as observed the indirect crossover. In the third study we compared the pressure behaviour of ordered and random alloy quantum wells of ZnCdSe/ZnSe in order to understand the confinement of the wavefunction in the ordered vs. random alloy materials. Finally, we have studied the temperature dependence of deformation potentials related the the Γ -X crossover in GaAs/AlAs superlattices.				
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Studies of ZnCdSe/ZnSe random and ordered alloy quantum wells under pressure. The ZnCdSe/ZnSe quantum well system has attracted a lot of interest because of the development of a blue-green solid state laser made from this material. The material parameters, such as the deformation potentials, however, are not well known for this alloy system.

The previous work^{1,2} constitutes a baseline for our present work on the ordered alloy quantum wells (aka digital quantum wells or DQW). There are certain questions about the ordered alloys and their quantum wells: for example, it is not clear whether the quantum wells of these alloys will have more or less wavefunction confinement within them, and that would define the degree of recombination that occurs in a laser made from the material. In Fig. 1 we show the photoluminescence spectra of a set of four DQW's, which were followed as a function of pressure up to 64 kbar. The layer sequence is (3 monolayers ZnSe/1 monolayer CdSe), which gives an average alloy content of $\text{Zn}_{0.75}\text{Cd}_{0.25}\text{Se}$. Surrounding the layer sequence are ZnSe barriers. The layer sequence is repeated to give wider quantum wells. The successive peaks are due to one, two, four and seven periods. Note that the one period sequence is really just *one monolayer* of CdTe, yet it gives a strong recombination signal. In order to compare these ordered alloys with a "random" alloy, we loaded in the same pressure cell a sample with three quantum wells (25, 50 and 150 Å) as well as a sample of bulk $\text{Zn}_{0.75}\text{Cd}_{0.25}\text{Se}$, whose deformation potentials will be used as a baseline in eight band **k.p** calculations.

This simultaneous study has allowed us to isolate the pressure induced changes due to quantization effects, as well as to study the differences between the random and ordered alloy quantum well systems. We find that the influence of ordering in these samples is evident at

¹ "Hydrostatic pressure studies of confined transitions in cubic $\text{Zn}_{1-x}\text{Cd}_x\text{Se}/\text{ZnSe}$ strained quantum wells", R.J. Thomas, H.R. Chandrasekhar, M. Chandrasekhar, N. Samarth, H. Luo, and J.K. Furdyna, Phys. Rev B **45** 9505 (1992).

² "Electronic Transitions in Semiconductor Quantum Wells and Epilayers Under Pressure," M. Chandrasekhar, and H.R. Chandrasekhar, review article in J. High Pressure Research, **9-10**, 57 (1992) .

thicknesses of $\sim 25\text{\AA}$ and less. We also find that a single period of the ordered alloy behaves quantum well like, despite with large overlap of the wavefunction with the barrier and extremely large confinement energy. We find from our studies that all the quantum well structures, be they random or ordered alloy, increase in energy with pressure *faster* than the bulk (Fig. 2). In order to understand these differences, our consultant, Prof. L.R. Ram-Mohan, performed a self consistent eight band **k.p** calculation. We find that we can account for about 25% of the differences between the bulk and quantum wells from changes in the well and barrier energy levels, strain, effective masses, and excitonic binding energy. The rest of the effect appears to have a different origin. We believe that the origin of the difference arises from the changing interlayer strain between the supposedly free standing bulk layer, and the buffer. We plan a photorefectance measurement of the bulk epilayer to track the interlayer strain felt by the layer under pressure. The importance of this measurement is that *all* previous studies of free standing layers have implicitly assumed that *no* additional strain is felt, which may not at all be the case.

This work is being conducted by a graduate student, Eric Baugher, who is supported by the related EPSCoR grant. The samples were obtained from J.K. Furdyna at the University of Notre Dame.

Study of III-V ordered alloys Spontaneous ordering of ternary alloys grown on misoriented substrates has been of considerable recent interest. Ordering induced band gap reduction, and valence band splittings exhibiting novel polarization properties have been investigated by theory and experiment. In publication 6, we discuss polarized photomodulated reflectivity (PR) and photoluminescence (PL) studies of MOCVD grown InGaP₂ epilayers lattice-matched to a GaAs substrate (Fig. 3a). These structures were grown on a (001) face with a misorientation of two degrees along $\langle 110 \rangle$. The high degree of ordering has enabled us to accurately measure the crystal field splitting and additional structure not reported in the PR spectra. For the electric field **E** parallel to $[110]$ two features in the PR spectra are seen; for $\mathbf{E} \parallel [\bar{1}10]$, however, additional features are observed (Figs 3 b and c). A comparison with the spectra of disordered samples of the same alloy composition has enabled a determination of the band gap reduction due to ordering. The linewidths of the PR peaks are approximately 5-10 meV which has enabled us to study them in detail as a function of hydrostatic pressure at cryogenic temperatures. The pressure dependence is slightly sublinear with the first order term of 8-9 meV/kbar for pressures well below the Γ -X crossover. Also observed is the indirect level crossing which occurs under pressure at about 40-kbar. A comparison of PR lineshapes at 1-bar is also presented at several commonly used experimental temperatures. The data indicate a substantial change in PR lineshapes.

Optical study of electrochemically produced quantum dots. Conventional nanosynthesis involves film growth followed by direct write nanolithography, which causes material damage and serial patterning. We are currently investigating nanostructures produced by an electrochemical process by Profs. A.E. Miller and S. Bandyopadhyay at the University of Notre Dame. This process is cheap and fast, allows parallel processing, and has shown state of the art spatial resolution. The results of our studies are shown in the panels of Fig. 4. All spectra were taken on samples that were electrodeposited with CdS for 30 sec, producing quantum "wires" about 100 Å wide and about 1000 Å long. In panel (a) we show the Raman spectra of one of the samples which is about 15 mm in diameter. The spectra were taken at several different spots. The shifts in the peak position show that there is some degree of strain in the sample. This is not unexpected, given that CdS is grown in the pores surrounded by amorphous alumina. It is worth noting, however, that these samples have material in the order of *picograms*, but can still be detected by Raman scattering. The CCD we have just purchased will be invaluable in studying these samples. In panel (b) we show the photoluminescence spectra, taken using the 3511 Å UV laser line. The spectrum is extremely broad, and weak, but nonetheless shows a *blue shift* in the peak intensity from the bulk of 200 meV. This is clear indication of quantum confinement. The reflectivity curve (c) and absorption curve (d) also show features at similar energies.

Γ-X mixing in the GaAs/AlAs superlattices

We are currently studying aspects of Γ-X mixing in the GaAs/AlAs superlattices. Excellent quality superlattices have been obtained from M. Melloch and A.K. Ramdas at Purdue University. There are several questions of the mixing that we are addressing with temperature and pressure studies. In the superlattices (such those grown with 2/2 to 20/20 monolayers) where the X band folds to form a pseudo direct gap, there are still several unanswered questions regarding the extent of mixing and its temperature dependence. We are currently studying these systems as a function of pressure and temperature. With pressure we alter the energy separations without affecting the extent of folding, while keeping a constant pressure and changing the temperature changes the mixing while keeping the energy separation fixed. We find that there are differences in the mixing. This work is currently being written up and is being performed by Chris Martin, a new graduate student and Suchi Guha, post doctoral associate partially supported by the ARO grant.

PUBLICATIONS:

- A comparative study of ordered alloy and Random alloy quantum wells of $\text{Zn}_{1-x}\text{Cd}_x\text{Se}/\text{ZnSe}$ under pressure, E.M. Baugher, M. Chandrasekhar, H.R. Chandrasekhar, H. Luo, J.K. Furdyna and L.R. Ram-Mohan, J. Phys. Chem. Solids **56** 323 (1995).
- Polarized photomodulated reflectivity and photoluminescence studies of ordered InGaP_2

under pressure, R.J. Thomas, H.R. Chandrasekhar, M. Chandrasekhar, E.D. Jones, and R.P. Schneider, J. Phys. Chem. Solids (accepted September 1994).

- Quasi-periodic quantum dot arrays produced by electrochemical synthesis, S. Bandyopadhyay, A.E. Miller, D-F Yue, G. Banerjee, R.E. Ricker, S. Jones, J.A. Eastman, E. Baugher, and M. Chandrasekhar, Nanotechnology, **7**, 360 (1996).
- Optical, electronic, magnetic and superconducting properties of quasi-periodic quantum dot arrays synthesized by a novel electrochemical technique, S. Bandyopadhyay, A.E. Miller, and M. Chandrasekhar, Invited paper at the SPIE International Symposium on Optoelectronic, Microphotonic and Laser Technologies, San Jose, CA, Feb 1995. Proc. SPIE **2397**, 12 (1995).

PRESENTATIONS:

- A comparative study of ordered alloy and random alloy quantum wells of $\text{Zn}_{1-x}\text{Cd}_x\text{Se}/\text{ZnSe}$ under pressure, E.M. Baugher, M. Chandrasekhar, H.R. Chandrasekhar, H. Luo, J.K. Furdyna and L.R. Ram-Mohan, J. Phys. Chem. Solids Sixth International Conference on High Pressures in Semiconductor Physics, Vancouver, August 1994.
- Electrosynthesis of quasi periodic semiconductor and ceramic superconductor quantum dot arrays, G. Banerjee, D.F. Yue, A.E. Miller, S. Bandyopadhyay, E. Baugher, M.E. Semmler, M. Chandrasekhar, and J.A. Eastman, 188th Meeting of the Electrochemical Society, Chicago, October 1995.

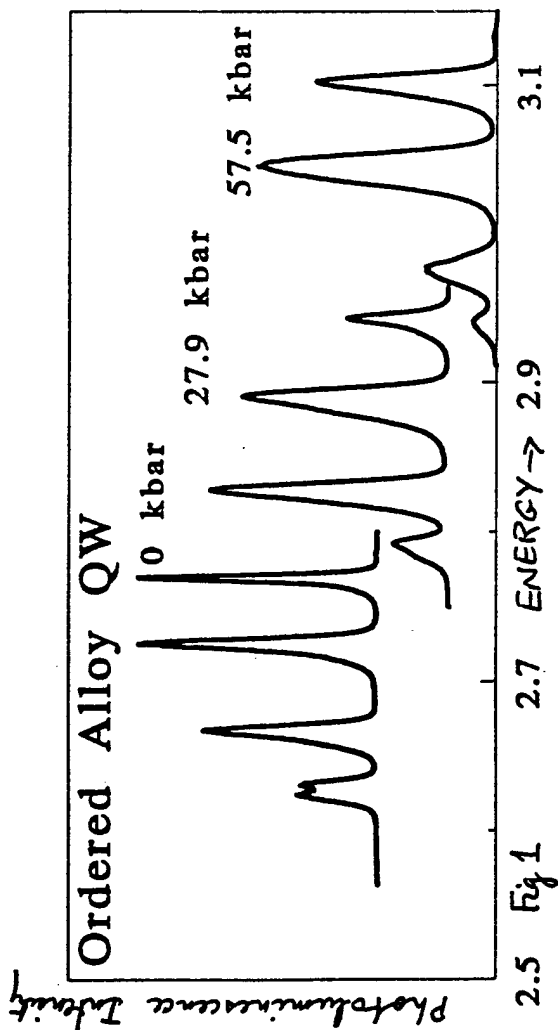
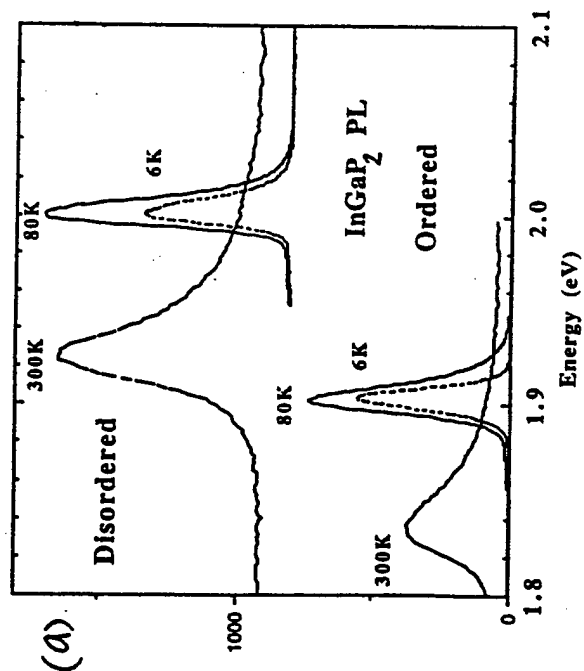
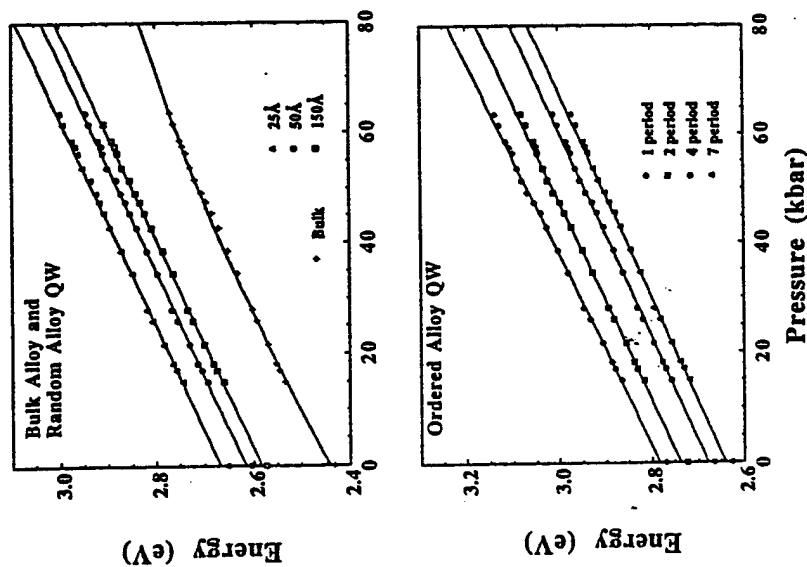


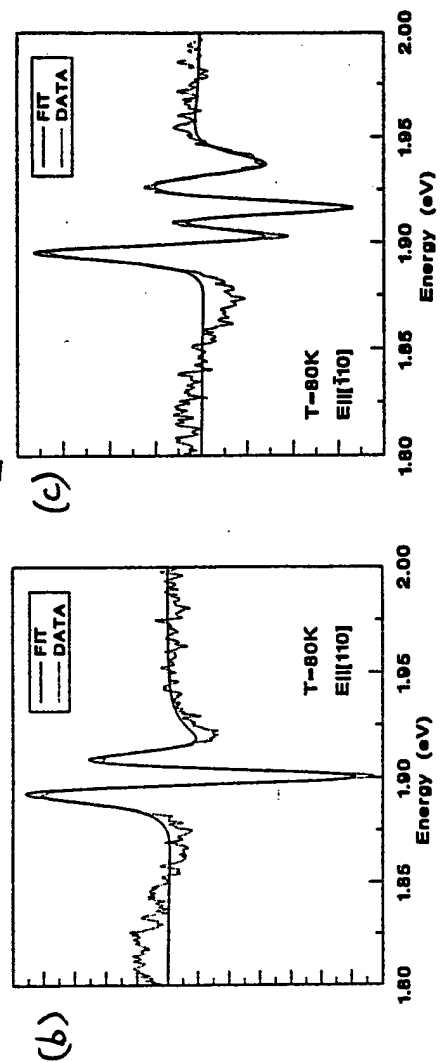
Fig. 1 (above) Photoluminescence spectra of ordered alloy quantum wells at several pressures, at 14K.

Fig. 2.(right) The pressure dependencies of random alloy and ordered alloy quantum wells, and bulk ZnCdSe.

Fig 3. (below) (a) Photoluminescence from ordered and random alloy InGaP₂ at several temperatures. (b and c) Photoreflectance of the ordered alloy InGaP₂ for two different polarizations.



InGaP₂



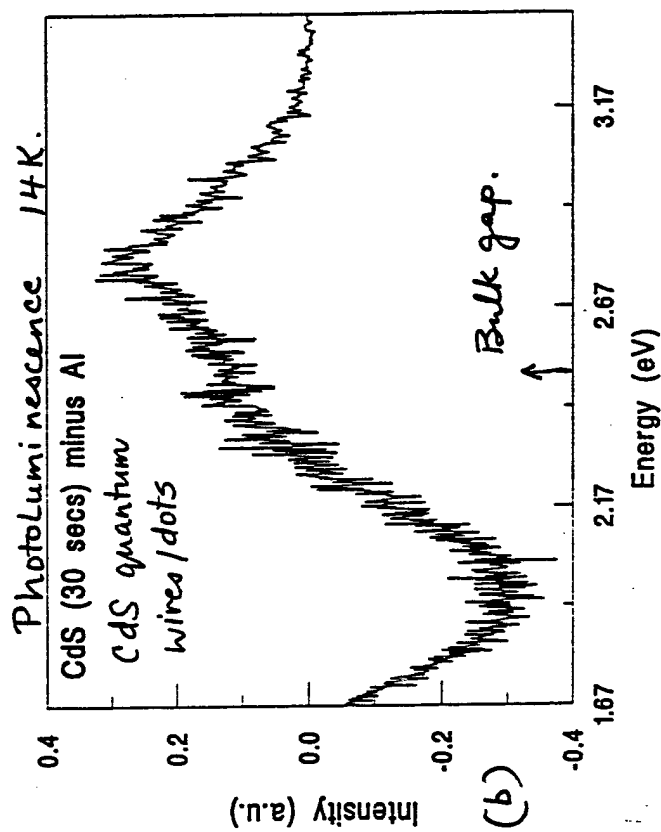
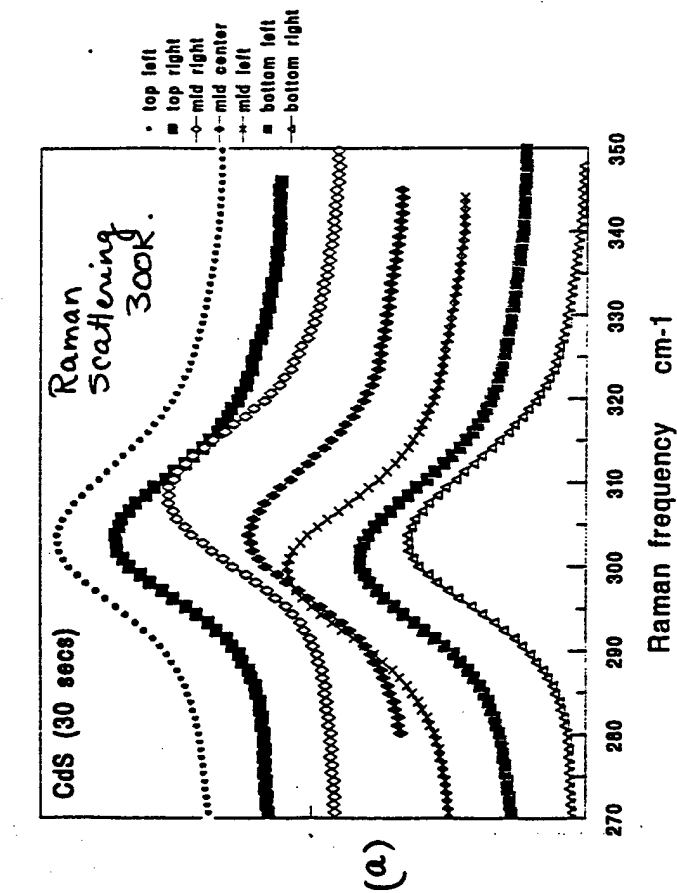


Fig. 4 (a) Raman scattering from a quantum dot sample, at several positions. (b) Photoluminescence spectrum, at 14 K. Note the blue shift in the peak energy by about 200meV from the bulk gap. (c and d) Reflectivity and absorption spectra, showing features at the same energy.

